

Final Project Summary Report
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Continued RXTE Observations of Three Blazars

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This project continued (during Cycle 3 of the RXTE mission) weekly observations of the quasars PKS 1510–089 and 3C 454.3 and the BL Lac object OJ 287. The data were analyzed by the PI and his graduate student. In the middle of Cycle 3, the PI changed the mode of observation of 3C 454.3, based on a report from another astronomer that observations with the Rosat satellite had found a strong confusing X-ray source about 45 arcmin away. The RXTE observations, in which the flux was measured while pointing directly at 3C 454.3 and then 15' from 3C 454.3, in the direction away from the confusing source. The flux decreased considerably, and so it appears that nearly all the X-ray flux measured by RXTE comes from the confusing source rather than the quasar.

OJ 287 was detected only at one epoch of the Cycle 3 observations. This corresponded to a particularly quiet period for this source, when its flux at other wavebands was also low. From the single epoch of detection, no conclusions can be drawn concerning the general nature of the X-ray emission from this object.

In contrast to the other two sources, the results of the observations of PKS 1510–089, when combined with data from Cycles 3 and 4, are very interesting. The RXTE (2.4–20 keV) and 14.5 GHz University of Michigan Radio Astronomy Observatory (UMRAO) light curves through the end of RXTE Cycle 4 are shown in Figure 1 and 4 for PKS 1510–089. Visual inspection of Figure 1 reveals an obvious correlation between the X-ray and 14.5 GHz light curves. While this is as expected in the SSC model in a source with simultaneous mm-wave (the photons thought to be scattered to X-ray energies) and cm-wave variations, the X-ray spectrum is flat (“energy” spectral index $\alpha = 0.2\text{--}0.5$, where $F_\nu \propto \nu^{-\alpha}$) compared with the mm-wave synchrotron spectrum ($\alpha \approx 0.8$). The PI is currently engaged in theoretical work to determine whether this is possible for an SSC model.

The X-ray–radio correlation is formalized in Figure 2, which plots the discrete cross-correlation function. The correlation is quite good (0.5) for all the data, peaking at a time delay of 13 days, with the X-ray lagging the radio. This unusual behavior is actually expected in cases in which the flaring region is moving relativistically directly toward the observer and the flare timescale is determined by light-travel delays (Marscher and Sokolov, in preparation). (Essentially, the scattering electrons must wait for the bulk of the flare photons to reach them before most of the scattering occurs.)

When the the cross-correlation is applied to the data before and after 1998.2 (Fig. 2, lower panels), the X-ray lag is found to be 16 days (with a high correlation of 0.7) in the early stage and weaker (0.4) in the later stage, with the latter corresponding to a 6-day lag of the radio relative to the X-ray. This change of behavior shows that several years of such observations are required to unravel the physics and geometry behind the variations in this source. The results from Cycle 3 are therefore part of a larger multi-year effort whose implications will be determined only after the entire multi-year program is completed.

The following publications resulted from this project:

Marscher, A.P., Marchenko-Jorstad, S.G., Mattox, J.R., Wehrle, A.E., and Aller, M.F. "High-Frequency Observations of Blazars," 2000, in *Astrophysical Phenomena Revealed by Space VLBI*, ed. H. Hirabayashi, P.G. Edwards, and D.W. Murphy (Sagami-hara, Japan: ISAS), 39-46.

Marscher, A.P. "Time Delays of Blazar Flares Observed at Different Wavebands," 2001, in *Probing the Physics of Active Galactic Nuclei by Multiwavelength Monitoring*, Astronomical Soc. Pacific Conf. Ser., in press.

Pursimo, T., ..., Marscher, A., *et al.* "Intensive Monitoring of OJ 287," 2000, *Astronomy & Astrophysics*, in press.

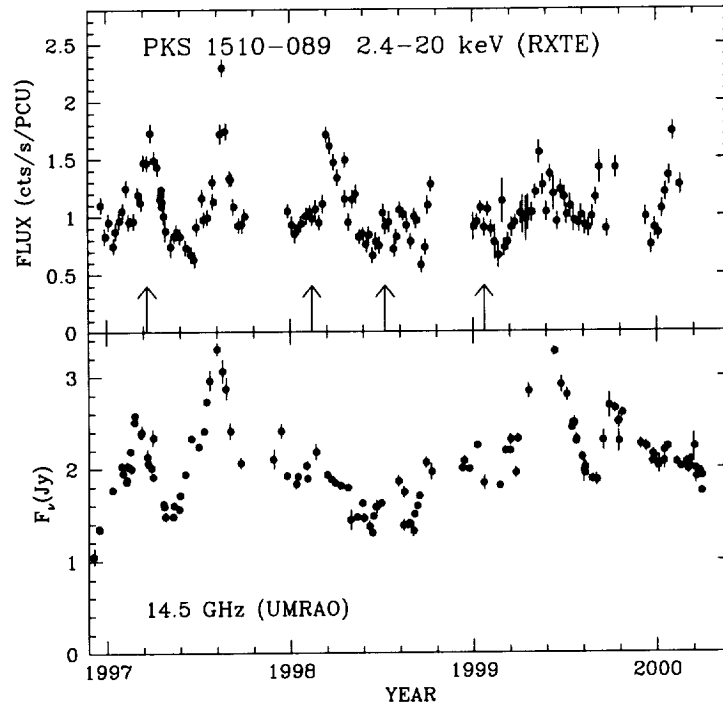


Fig. 1. RXTE 2.4–20 keV and UMRAO 14.5 GHz light curves (from our Cycle 3 and 4 programs) of PKS 1510–089 from the end of 1997 to early 2000. The data show a high degree of variability that is well-correlated with the radio variability. Arrows show times of known superluminal ejections.

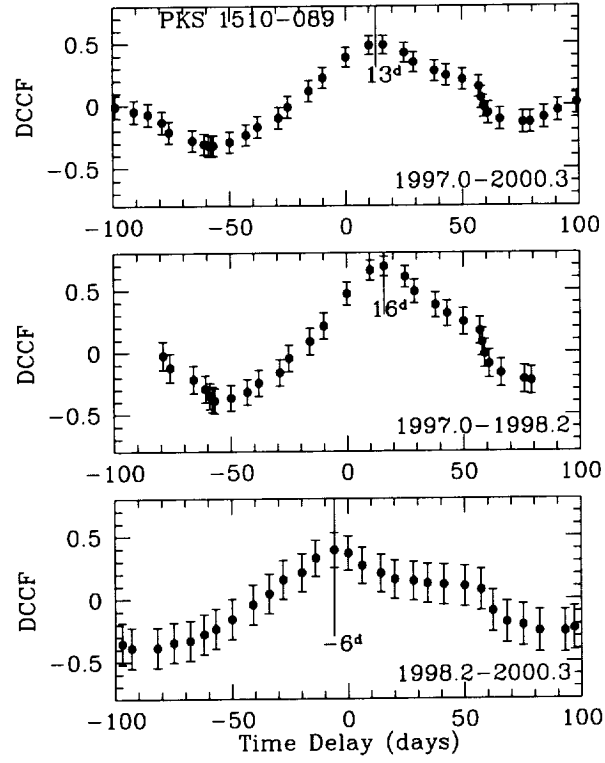


Fig. 2. Discrete cross-correlation function of the 14.5 GHz and X-ray light curves of PKS 1510-089. A negative time delay corresponds to the X-rays variations leading the radio.